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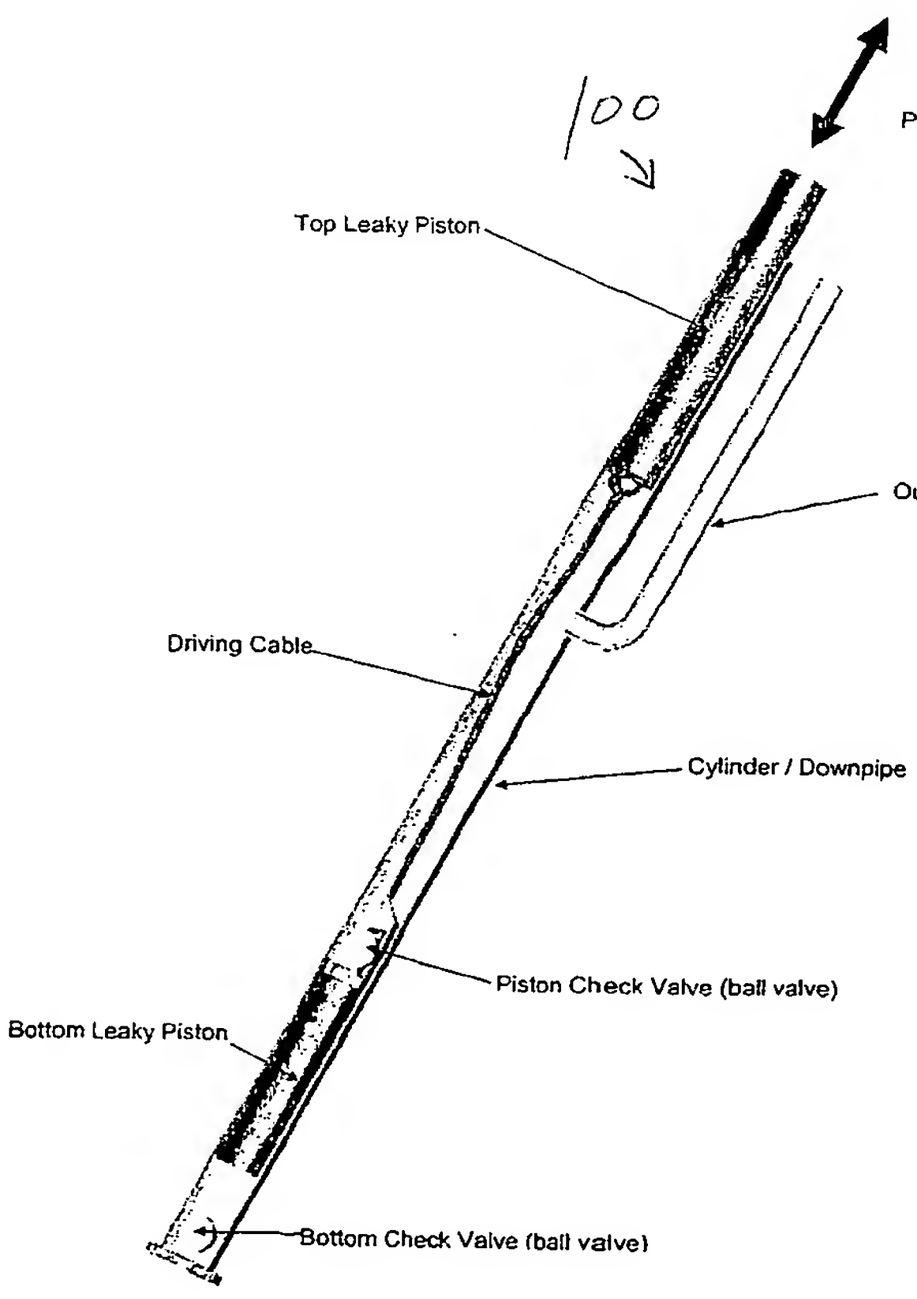
[Continued on next page]

(54) Title: DEEP WELL IRRIGATION PUMP



(57) Abstract: Provided herein are exemplary embodiments of an efficient pump apparatus. In one embodiment the pump apparatus comprises a piston assembly loosely disposed within a cylinder. The piston assembly includes a driving cable connecting a top leaky piston and a bottom leaky piston having a check valve connected thereto. The cylinder includes an outlet pipe at an upper portion thereof and a check valve located at a lower end of the cylinder. The pistons move in the cylinder at a velocity relative to the conduit such that as the pistons move along the cylinder they create a substantial tortuous leak path forming a hydrodynamic seal between the pistons and the cylinder.

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TITLE

Deep Well Irrigation Pump

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to U.S. Application Number 60/519,887, filed November 14, 2003, the entire disclosure of which is hereby incorporated by reference as if set forth at length herein.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

REFERENCE OF A "MICROFICHE APPENDIX"

Not applicable

FIELD OF THE INVENTION

The present invention relates generally to pumping devices.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention are now briefly described with reference to the following drawings:

FIG. 1 depicts one aspect of the present invention in accordance with the teachings presented herein.

FIG. 2 depicts a second aspect of the present invention in accordance with the teachings presented herein.

FIG. 3 depicts a third aspect of the present invention in accordance with the teachings presented herein.

FIG. 4 depicts a fourth aspect of the present invention in accordance with the teachings presented herein.

FIG. 5 depicts a fourth aspect of the present invention in accordance with the teachings presented herein,

FIG. 6 depicts a fourth aspect of the present invention in accordance with the teachings presented herein

DESCRIPTION OF THE INVENTION

The aspects, features and advantages of the present invention will become better understood with regard to the following description with reference to the accompanying drawings. What follows are preferred embodiments of the present invention. It should be apparent to those skilled in the art that the foregoing is illustrative only and not limiting, having been presented by way of example only. All the features disclosed in this description may be replaced by alternative features serving the same purpose, and equivalents or similar purpose, unless expressly stated otherwise. Therefore, numerous other embodiments of the modifications thereof are contemplated as falling within the scope of the present invention as defined herein and equivalents thereto.

FIG. 1 depicts an exemplary embodiment of an efficient pump apparatus 100 constructed in accordance with the present invention. As shown, the pump apparatus includes at a piston assembly loosely disposed within a cylinder. The piston assembly includes a driving cable connecting a top leaky piston and a bottom leaky piston having a check valve connected thereto.. The cylinder includes an outlet pipe on a upper portion thereof and a check valve located at a lower end of the cylinder. Key features of the pump apparatus 100 will now be described below.

Long Loose Leaky Piston

In an exemplary embodiment, the present invention employs two "long loose leaky pistons", having a length greater than that of conventional washers used in prior art rope and washer pumps. The "long loose leaky pistons", when reciprocated up and down in the cylinder, displace a volume of fluid and create a pressure head. The loose fit between the piston and the cylinder accommodates extremely loose dimensional tolerances (like those found in the inconsistent pipes that are available in many developing countries) and also has many other advantages listed below. Instead of having a tight fitting seal between the piston and cylinder they are both made of cylindrical pipes with the outer diameter of the piston being slightly smaller (up to a few % of the diameter) than the inner diameter of the cylinder. As the piston moves, the length of the piston creates a tortuous leak path making a hydrodynamic seal and allowing the piston to pressurize the fluid. The longer the piston, and the smaller the gap the more efficient this seal becomes.

The advantages of a "long-loose leaky piston" over other prior art pistons, include:

(1) There is very little friction between the piston and cylinder and this friction does not vary much with depth of pumping. The gap between the piston and cylinder is filled with fluid making them hydro-dynamically lubricated. In a normal piston and cylinder pump there is a piston cup (often leather or rubber) where the sealing force and thus the frictional force increases linearly with the depth of the pumping and greatly increases the pumping forces required. This new pump can thus be very energy efficient compared to a normal piston and cylinder pump.

(2) The hydrodynamic lubrication means that for clean fluids there is almost no problem with wear on either the piston or cylinder unlike for traditional piston pumps where wear is a major issue and requires the cylinder to be made of hardened material and the piston ring/cup to be replaced on a regular basis. (friction and wear are of-course closely related in this instance).

(3) Because there is no physical contact between the piston and cylinder the force required to lower the piston is also greatly reduced - it is now only the hydrodynamic drag thru the valve and this allows us to rely on gravity to lower the piston. In regular piston cylinder pumps piston rods are required to push the piston down (to overcome the frictional forces between the piston cup and the cylinder) on the return stroke.

(4) Because the leaky piston has a substantial leak path the pumping efficiency of the pump is highly velocity dependent (unlike for a traditional piston and cylinder pump). The faster the piston moves the more efficient the pump becomes. (And it also turns out that the longer the stroke the more efficient the pump becomes since less time is taken with the valves open between strokes and the water has to be re-accelerated fewer times - but this last point is also true on traditional piston pumps).

(5) Pumping efficiency is also dependent on the cylinder-piston gap and on the length of the piston (length of the leak path). A longer piston and tighter gap decreases the leakage and increases the volumetric efficiency but also increases the hydrodynamic drag so eventually in the limit it also decreases the energy efficiency. In a normal piston and cylinder pump the volumetric efficiency is

pretty much constant (because the tight seal between piston and cylinder) while the energy efficiency decreases with depth of pumping because of greatly increased frictional losses.

(6) A leaky piston is also much less dependent on precise dimensional tolerances between the piston and cylinder compared to a traditional piston pump, and also the surface quality of the cylinder (which usually has to be a very smooth machined surface) is no longer such a major issue. This means that a pump with a leaky piston can be made from fairly rough materials. However, dimensional straightness over the length of the piston and cylinder is still critical. This low need for exact tolerances means that it is possible for the pumping pipe to also act as the cylinder/cylinders, which is another big advantage of the design.

Flexible Cable Drive

In an exemplary embodiment, the present invention further employs a flexible cable drive (such as a chain, rope, wire, or some other flexible member). Most reciprocating deep well pumps use a rigid driving rod that can push the piston down (and pull it up). This design requires more material and bearing infrastructure to prevent the rod from buckling. The present invention uses gravity to return the bottom piston to its bottom position offering a cheaper, easier to assemble/transport, and reliable solution. There is no contact between the piston and the cylinder therefore no real drag occurs between the piston and the cylinder.

Top Piston and Bottom Piston

To enable a pressure head above ground, the present invention (which is very important for many applications including irrigation) includes a top leaky piston without

any additional valves (other than the two check valves in the bottom cylinder and piston). On the pressure stroke (forcing the top piston down), water is pressurized against the existing bottom check valve and out the outlet at the top of the well. This embodiment reduces the number of valves and seals.

It turns out, however, that the addition of another one-way outlet valve in the outlet pipe increases the efficiency of the pump. Without this extra valve the bottom loose piston gap sees the full (below ground and above ground) pressure head on the up stroke and it leaks a lot more and reduces efficiency. Another embodiment of the present invention employs an outside sleeve over the top cylinder with an outlet pipe only at the top end of it, instead of an outlet pipe at the bottom of the top cylinder. The addition of the outside sleeve feature keeps the overall diameter of the down hole components to a minimum allowing the pump to be used in a small diameter bore hole.

Additional Embodiments of the Present Invention

In accordance with an alternative embodiment of the present invention, a pump could be constructed with only the bottom leaky piston and a flexible tension member (rope, cable chain, etc) pulling it up and letting it drop by gravity. A pump can be built without the top leaky piston and without the outlet pipe.

In accordance with a second alternative embodiment of the present invention, any type of drive mechanism could be connected to the pump mechanism, including but not limited to other manual drives, a gasoline engine or electric motor.

In accordance with a third alternative embodiment of the present invention, a flexible piston option would work in the case where there is a non-straight cylinder. Here the hydrodynamic pressure would act to ensure that the piston flexes so that it won't get

jammed in the cylinder. This would be very useful for pumping fluids through curved pipes.

In accordance with a fourth alternative embodiment of the present invention, a double reciprocating piston pump (with two pistons one above the other operating 180 degrees out of synch) may be used, with two cables going down the pumping tube.

In accordance with a fifth alternative embodiment of the present invention, any type of valve could be used.

FIGS 2A-D depict details of the bottom leaky piston and FIGS 3A-B depict details of the top leaky piston.

FIGS. 4A-D depict aspects of alternative exemplary embodiments of pump apparatus 100.

FIGS. 5A-D depict of alternative exemplary embodiments of pump apparatus 100.

FIG. 6 depicts an assembly incorporating an exemplary embodiment of pump apparatus 100.

The present invention pump apparatus 100 is operated by repeatedly driving the top piston up and down while the bottom cylinder and check valve are submersed in a fluid. The fluid is pulled into the bottom check valve on the up stroke and is forced out of the outlet pipe under pressure during the down stroke. The two pistons are connected by a flexible tension member (rope, cable chain) that pulls up the bottom piston on the up stroke and then gravity returns the bottom piston to place on the down stroke. The pump 100 may be driven by two foot operated treadles like a small stair master machine.

The pump 100 adds a variable mechanical advantage on the drive mechanism giving a high mechanical advantage at the start of each stroke (allowing for increased

acceleration) and a low mechanical advantage at the end of each stroke (allowing for increased velocity) thereby maximizing the average piston velocity over the stroke and increasing the overall energy efficiency of the pump. This is an attractive feature for a human powered pump.

Having now described preferred embodiments of the invention, it should be apparent to those skilled in the art that the foregoing is illustrative only and not limiting, having been presented by way of example only. All the features disclosed in this specification (including any accompanying claims, abstract, and drawings) may be replaced by alternative features serving the same purpose, and equivalents or similar purpose, unless expressly stated otherwise. Therefore, numerous other embodiments of the modifications thereof are contemplated as falling within the scope of the present invention as defined by the appended claims and equivalents thereto.

CLAIMS

What is claimed is:

1. An energy efficient pump apparatus, comprising:

a first closed conduit having first and second ends;

a first movable piston with a closed end having an effective length A greater than the median radius of said conduit, said first piston loosely disposed within said first closed conduit such that a gap having a predefined median size is formed between said first piston and said first closed conduit;

wherein said first piston is movable in said closed conduit at a velocity relative to said conduit such that as said first piston moves along said closed conduit said first piston creates a substantial tortuous leak path forming a hydrodynamic seal between said first piston and said closed conduit thereby enabling said first piston to displace fluid along said closed conduit; and;

wherein the efficiency of said hydrodynamic seal is based on said predefined median size of said gap, said effective length A of said first piston and said velocity of said piston.

2. A pump apparatus as in claim 1 wherein said first piston further includes a one-way valve disposed therein; wherein when said first piston is moved back and forth along said closed conduit, said piston pulls and pumps fluid along said closed conduit.

3. A pump apparatus as in claim 2 wherein said closed conduit is positioned at an angle other than horizontal and said closed conduit further includes a one-way inlet valve at a lower portion thereof; wherein when said first piston is moved up and down along said closed conduit, fluid is pulled into and pumped up said first closed conduit.

4. A pump apparatus as in claim 3 further comprising a drive member connected to a top end of said first piston and operable to move said first piston up and down along said closed conduit.

5. A pump apparatus as in claim 4 wherein said drive member is flexible.

6. A pump apparatus as in claim 5 further comprising a pipe having top and second ends; said second end of said pipe attached to said top end of said first closed conduit; wherein during the up-stroke of said pump apparatus, said first piston is pulled up by said drive member and during the down-stroke of said pump apparatus, said first piston is pulled down by gravity, thereby pulling and pumping fluid into and up said pipe.

7. A pump apparatus as in claim 6 further comprising:

a second closed conduit having top and second ends,

a second movable piston loosely disposed within said second closed conduit such that a gap having a predefined median size is formed between said second piston and said second closed conduit; said second piston having a rigid drive member connected thereto;

said second end of said second closed conduit attached to said first end of said pipe;

an outlet at the lower end of said second closed conduit;

wherein during operation of said pump apparatus said first and second pistons move in said respective closed conduits to facilitate fluid flow into said first closed conduit, into and up said pipe on the up-stroke, and out of said outlet under pressure on the down-stroke.

8. A pump apparatus as in claim 7 further comprising an outlet pipe connected to the outlet at the lower end of said second closed conduit and a one-way outlet valve disposed in said outlet pipe to limit the amount of force required to move said first and second pistons on the up-stroke.

9. A pump apparatus as in claim 7 further comprising:

a closed sleeve outlet conduit comprising a closed sleeve and an outlet pipe connected to an upper portion of said closed sleeve;

said closed sleeve outlet conduit covering said second conduit and creating a sleeve-conduit gap between the outer walls of said second conduit and the inner walls of said closed sleeve, such that said sleeve-conduit gap is sealed both at the bottom and the top of said closed sleeve outlet conduit, and such that any fluid flowing through said outlet at the lower end of said second closed conduit flows into said sleeve-conduit gap;

wherein during operation of said pump apparatus said first and second pistons move in said respective closed conduits to facilitate fluid flow into said first closed conduit, into and up said pipe and into said second closed conduit during the up-stroke, and though said opening of said second closed conduit, into said sleeve-conduit gap and out of said outlet pipe under pressure during the down-stroke.

10. A pump apparatus as in claim 9 wherein said sleeve outlet pipe includes a one-way valve disposed therein to limit the amount of force required to move said first and second pistons on the up stroke.

11. A energy efficient pump apparatus to pressurize, displace and pump a volume of fluid, comprising:

a closed conduit;

a piston assembly comprising:

a top piston having a length-wise dimension greater than that of a washer;

a bottom piston having a length-wise dimension greater than that of a washer and

flexible drive member connecting said top and bottom pistons;

said piston assembly loosely disposed within said closed conduit such that a gap having a predefined size is formed between said pistons and said closed conduit;

said piston assembly movable in said closed conduit such that as said top and bottom pistons move said top and bottom pistons create a substantial tortuous leak path forming a hydrodynamic seal between said top and bottom pistons and said closed conduit thereby enabling said piston assembly to displace said fluid;

wherein the efficiency of said hydrodynamic seal is based on said predefined size of said gap and said length-wise dimensions of said top and bottom pistons.

12. A pump apparatus as in claim 11 wherein said closed conduit is a cylinder having an upper portion.

13. A pump apparatus as in claim 12 further comprising an outlet connected to a top region of said upper cylinder portion and a one-way outlet valve disposed in said outlet for removal of said displaced fluid.

14. A pump apparatus as in claim 13 wherein said outlet is a sleeve outlet pipe.

15. A pump apparatus as in claim 11 wherein said bottom piston includes a one-way inlet valve for fluid upflow during up stroke operation of said apparatus.

16. A pump apparatus as in claim 11 wherein said flexible drive member provides gravitational return stroke during operation of said apparatus.

17. A pump apparatus as in claim 11 wherein said flexible drive member is a cable, rope, chain, wire or a combination of the foregoing.

18. A energy efficient pump apparatus to pressurize, displace and pump a volume of fluid, comprising:

a frame;

a cylinder and pipe assembly mounted on said frame at an angle other than horizontal and comprising:

a pipe, a top cylinder, and a bottom cylinder connected to said top cylinder by said pipe;

said bottom cylinder having a bottom check valve;

said top cylinder having an outlet connected to an upper region of said top cylinder and a one-way outlet valve disposed in said outlet for removal of said displaced fluid;

a piston assembly having:

a valve-less top piston having a length-wise dimension greater than that of a washer with a closed end,

a hollow bottom piston having a length-wise dimension greater than that of a washer and further having a one-way fluid inlet valve that allows fluid to flow upwards therethrough during up stroke operation of said apparatus;

a flexible tension member connecting said top and bottom pistons at a distance such that when said piston assembly is disposed within the said cylinder and pipe assembly, said top piston is inside said top cylinder and said bottom piston is inside said bottom cylinder;

said piston assembly loosely disposed within said cylinder and pipe assembly and forming a gap having a predefined size between said pistons and said cylinders;

said piston assembly movable in said cylinder and pipe assembly such that as said piston assembly moves said top and bottom pistons create a substantial tortuous leak path forming a hydrodynamic seal between said pistons and said cylinder thereby enabling said top and bottom pistons to pressurize and displace said volume of fluid;

wherein the efficiency of said hydrodynamic seal is based on said predefined size of said gap and said lengths of said top and bottom pistons.

19. A pump apparatus as in claim 18 to wherein said pipe is a rigid or a flexible pipe.

20. A pump apparatus as in claim 18 wherein said outlet is a sleeve outlet pipe.

21. A pump apparatus as in claim 18 wherein said flexible drive member provides gravitational return stroke during operation of said apparatus.

22. A pump apparatus as in claim 18 wherein said flexible drive member is a cable, rope, chain, wire or a combination of the foregoing.

23. An energy efficient pump apparatus, comprising:

a first closed conduit having first and second ends;

a first movable piston with a closed end; said first piston loosely disposed within said first closed conduit such that a gap having a predefined median size is formed between said first piston and said first closed conduit;

wherein said first piston is movable in said closed conduit at a velocity relative to said conduit such that as said first piston moves along said closed conduit said first piston creates a substantial tortuous leak path forming a hydrodynamic seal between said

first piston and said closed conduit thereby enabling said first piston to displace fluid along said closed conduit; and;

the efficiency of said hydrodynamic seal is based on said predefined median size of said gap and said velocity of said piston;

wherein said first piston further includes a one-way valve disposed therein; wherein when said first piston is moved back and forth along said closed conduit, said piston pulls and pumps fluid along said closed conduit.

24. A pump apparatus as in claim 23 wherein said closed conduit is positioned at an angle other than horizontal and said closed conduit further includes a one-way inlet valve at a lower portion thereof; wherein when said first piston is moved up and down along said closed conduit, fluid is pulled into and pumped up said first closed conduit.

25. A pump apparatus as in claim 24 further comprising a drive member connected to a top end of said first piston and operable to move said first piston up and down along said closed conduit.

26. A pump apparatus as in claim 25 wherein said drive member is flexible.

27. A pump apparatus as in claim 26 further comprising a pipe having top and second ends; said second end of said pipe attached to said top end of said first closed conduit; wherein during the up-stroke of said pump apparatus, said first piston is pulled up by said drive member and during the down-stroke of said pump apparatus, said first piston is pulled down by gravity, thereby pulling and pumping fluid into and up said pipe.

28. A pump apparatus as in claim 27 further comprising:

a second closed conduit having top and second ends,

a second movable piston loosely disposed within said second closed conduit such that a gap having a predefined median size is formed between said second piston and said second closed conduit; said second piston having a rigid drive member connected thereto;

said second end of said second closed conduit attached to said first end of said pipe;

an outlet at the lower end of said second closed conduit;

wherein during operation of said pump apparatus said first and second pistons move in said respective closed conduits to facilitate fluid flow into said first closed conduit, into and up said pipe on the up-stroke, and out of said outlet under pressure on the down-stroke.

29. A pump apparatus as in claim 28 further comprising an outlet pipe connected to the outlet at the lower end of said second closed conduit and a one-way outlet valve disposed in said outlet pipe to limit the amount of force required to move said first and second pistons on the up-stroke.

30. A pump apparatus as in claim 28 further comprising:

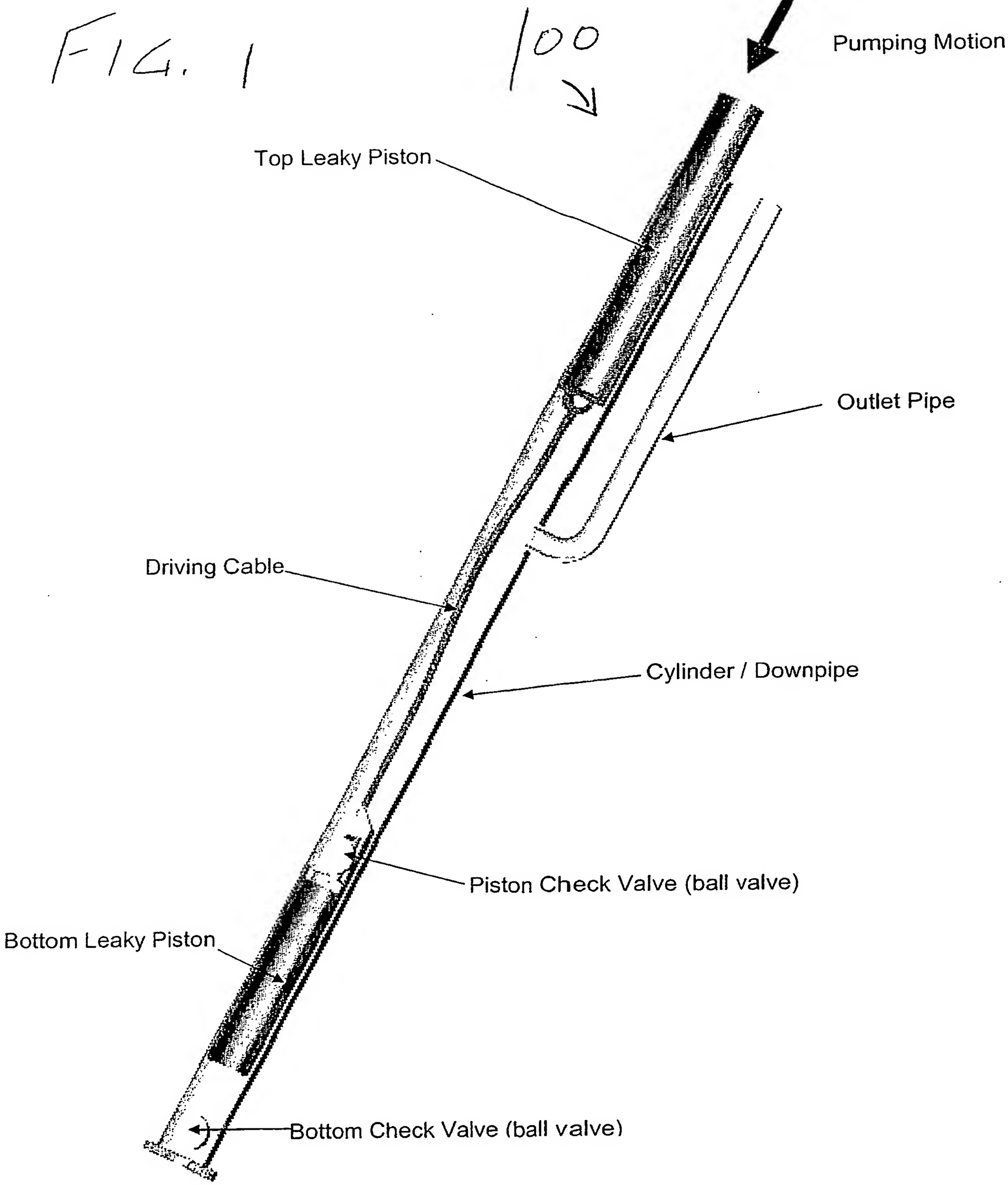
a closed sleeve outlet conduit comprising a closed sleeve and an outlet pipe connected to an upper portion of said closed sleeve;

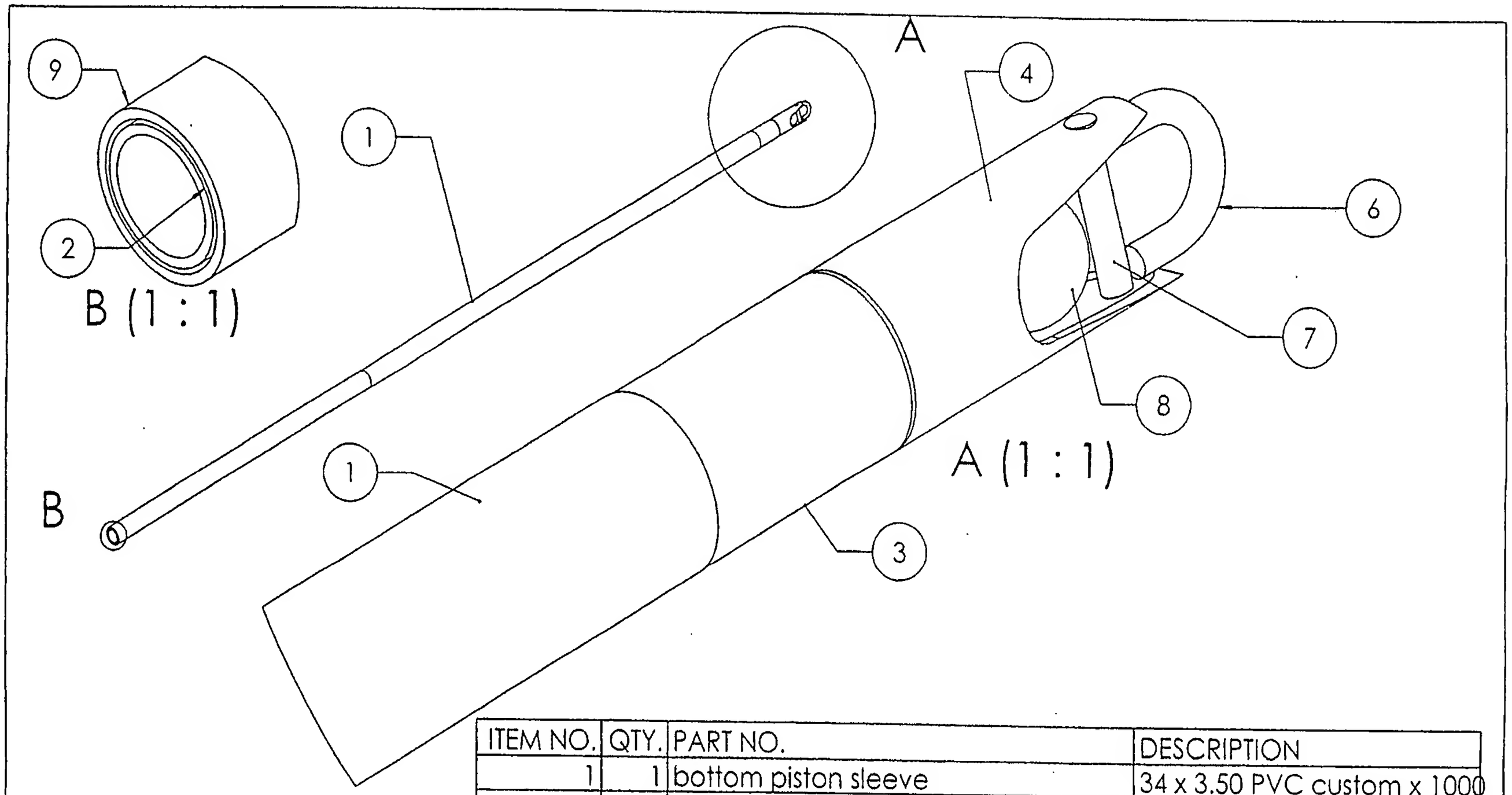
said closed sleeve outlet conduit covering said second conduit and creating a sleeve-conduit gap between the outer walls of said second conduit and the inner walls of said closed sleeve, such that said sleeve-conduit gap is sealed both at the bottom and the top of said closed sleeve outlet conduit, and such that any fluid flowing through said outlet at the lower end of said second closed conduit flows into said sleeve-conduit gap;

wherein during operation of said pump apparatus said first and second pistons move in said respective closed conduits to facilitate fluid flow into said first closed conduit, into and up said pipe and into said second closed conduit during the up-stroke, and though said opening of said second closed conduit, into said sleeve-conduit gap and out of said outlet pipe under pressure during the down-stroke.

31. A pump apparatus as in claim 30 wherein said sleeve outlet pipe includes a one-way valve disposed therein to limit the amount of force required to move said first and second pistons on the up stroke.

FIG. 1

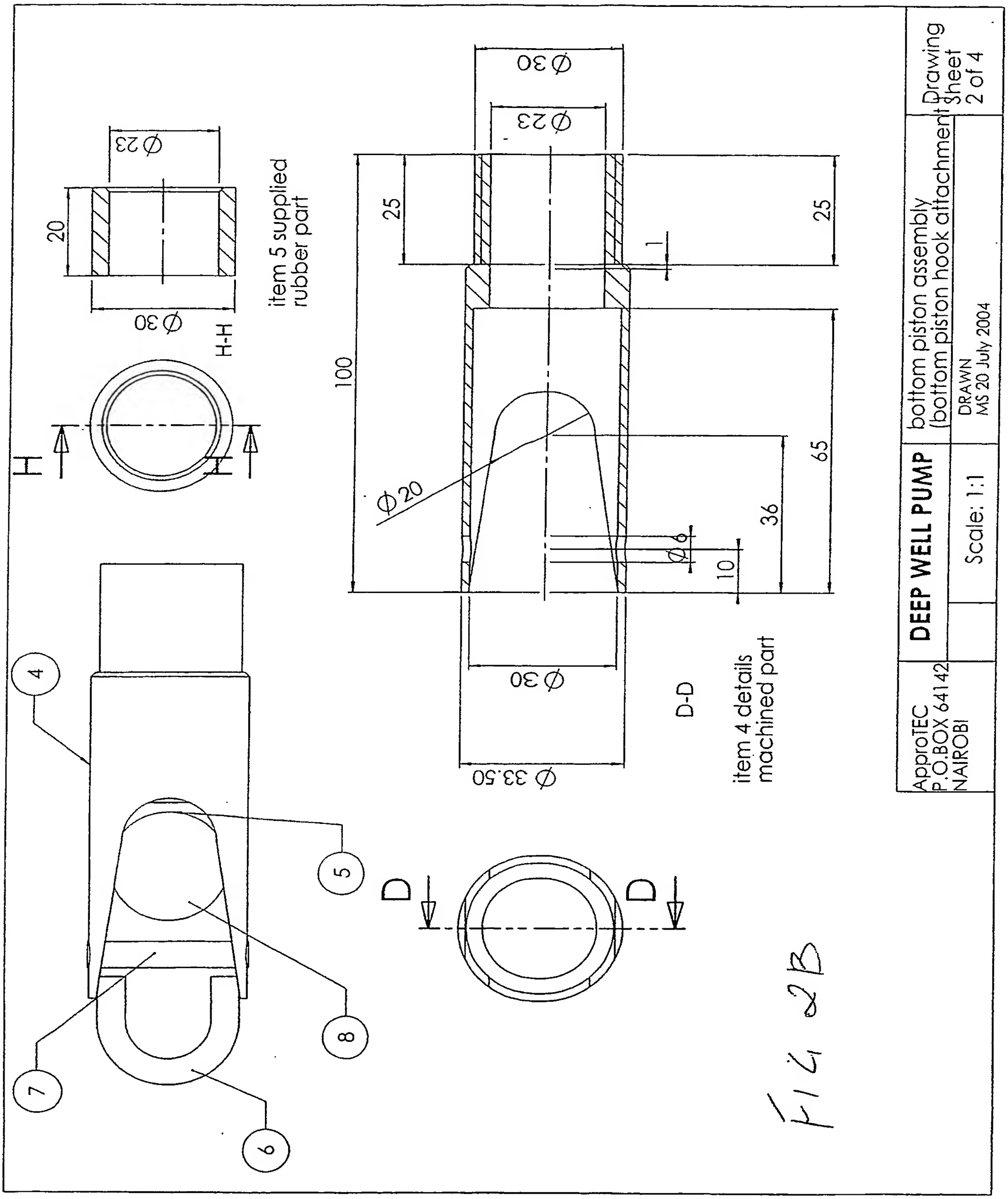

100
Pumping Motion
Top Leaky Piston
Outlet Pipe
Driving Cable
Cylinder / Downpipe
Piston Check Valve (ball valve)
Bottom Leaky Piston
Bottom Check Valve (ball valve)



ITEM NO.	QTY.	PART NO.	DESCRIPTION
1	1	bottom piston sleeve	34 x 3.50 PVC custom x 1000
2	1	bottom piston insert	27 x 2 3/4" class A x 1665
3	1	valve adaptor nipple	1" BPC x 50
4	1	bottom piston hook attachment	BSS 38 x 100
5	1	ball valve 23mm seat	moulded supplied part
6	1	hook attachment	6 round bar x 130
7	1	ball retainer rod2	dia. 6 round bar x 34
8	1	25mm ball	standard part
9	1	bottom piston added weight	33 x 2 RST x 650

FIG 2A

ApproTEC P.O.BOX 64142 NAIROBI	**DEEP WELL PUMP**	bottom piston assembly (assembly details)	Drawing Sheet 1 of 4
	Scale 1:10	DRAWN MS 20 July 2004	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Ø30
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item 5 supplied
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10
Ø30
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item 4 details
machined part
4
5
8
7
6
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Drawing
Sheet
2 of 4
piston assembly
piston hook attachment
DEEP WELL PUMP
bottom pis
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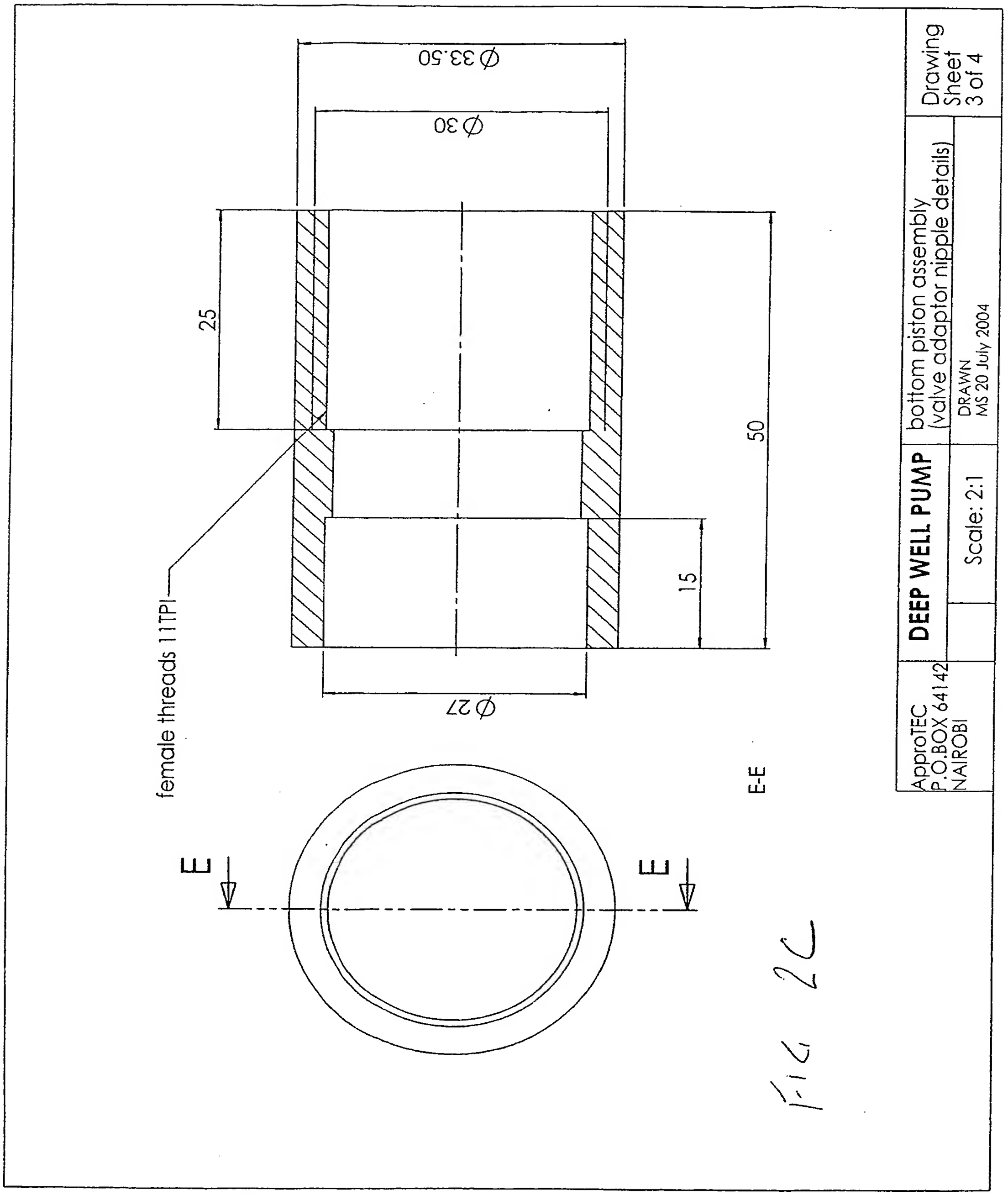
ApproTEC
P.O.BOX 64142
NAIROBI

FIG 2B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female threads 11TPI
E
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E-E
Drawing Sheet 3 of 4
bottom piston assembly (valve adaptor nipple details)
DRAWN MS 20 July 2004
DEEP WELL PUMP
Scale: 2:1
Appropriate Technology P.O.BOX 64142 NAIROBI

FIG 2C

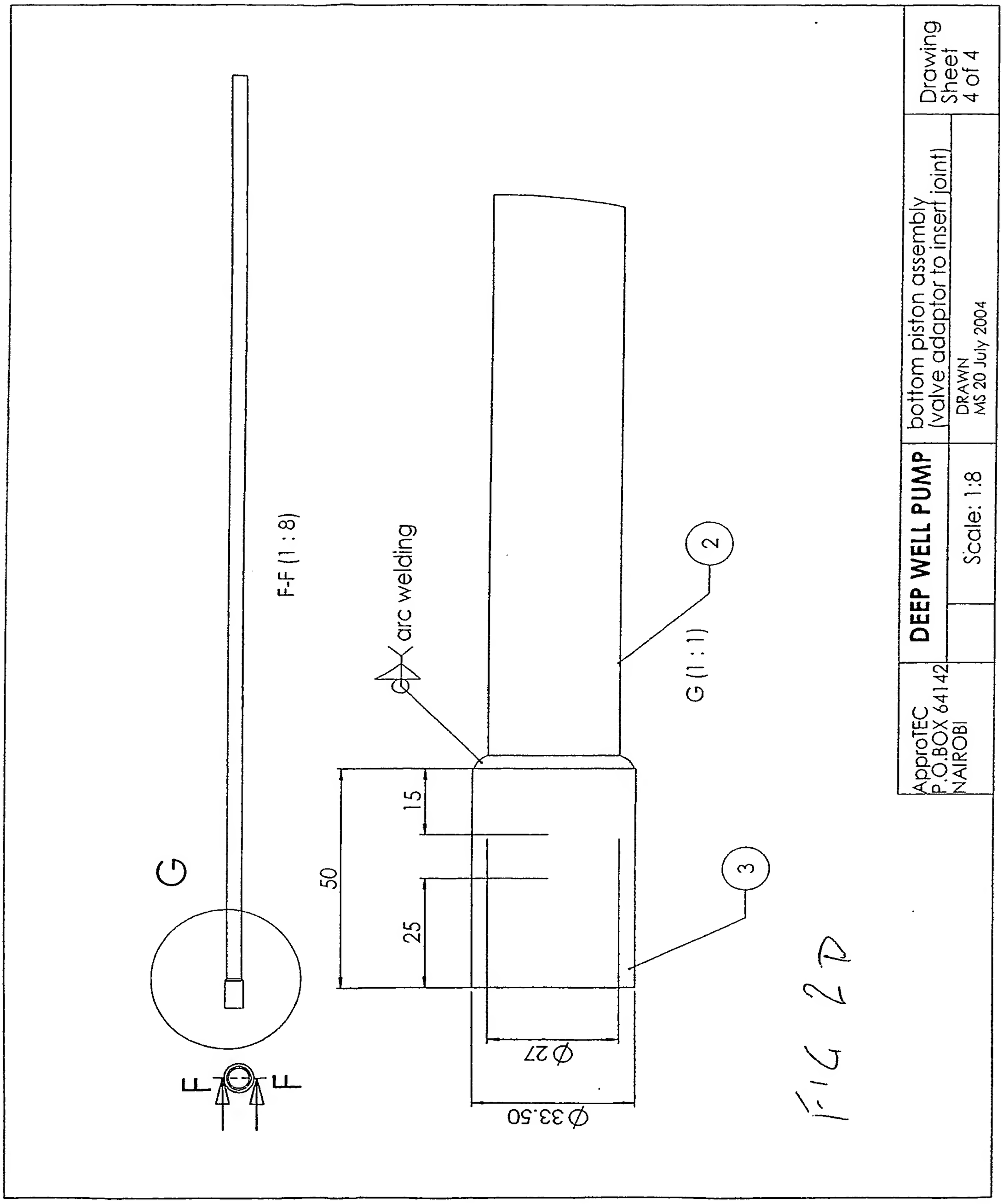

Drawing Sheet 4 of 4
bottom piston assembly (valve adaptor to insert joint)
DEEP WELL PUMP
Scale: 1:8
DRAWN MS 20 July 2004
ApproTEC P.O.BOX 64142 NAIROBI
F-F (1 : 8)
arc welding
G (1 : 1)
2
3
15
50
25
Ø 27
Ø 33.50
G
E
E

FIG 2D

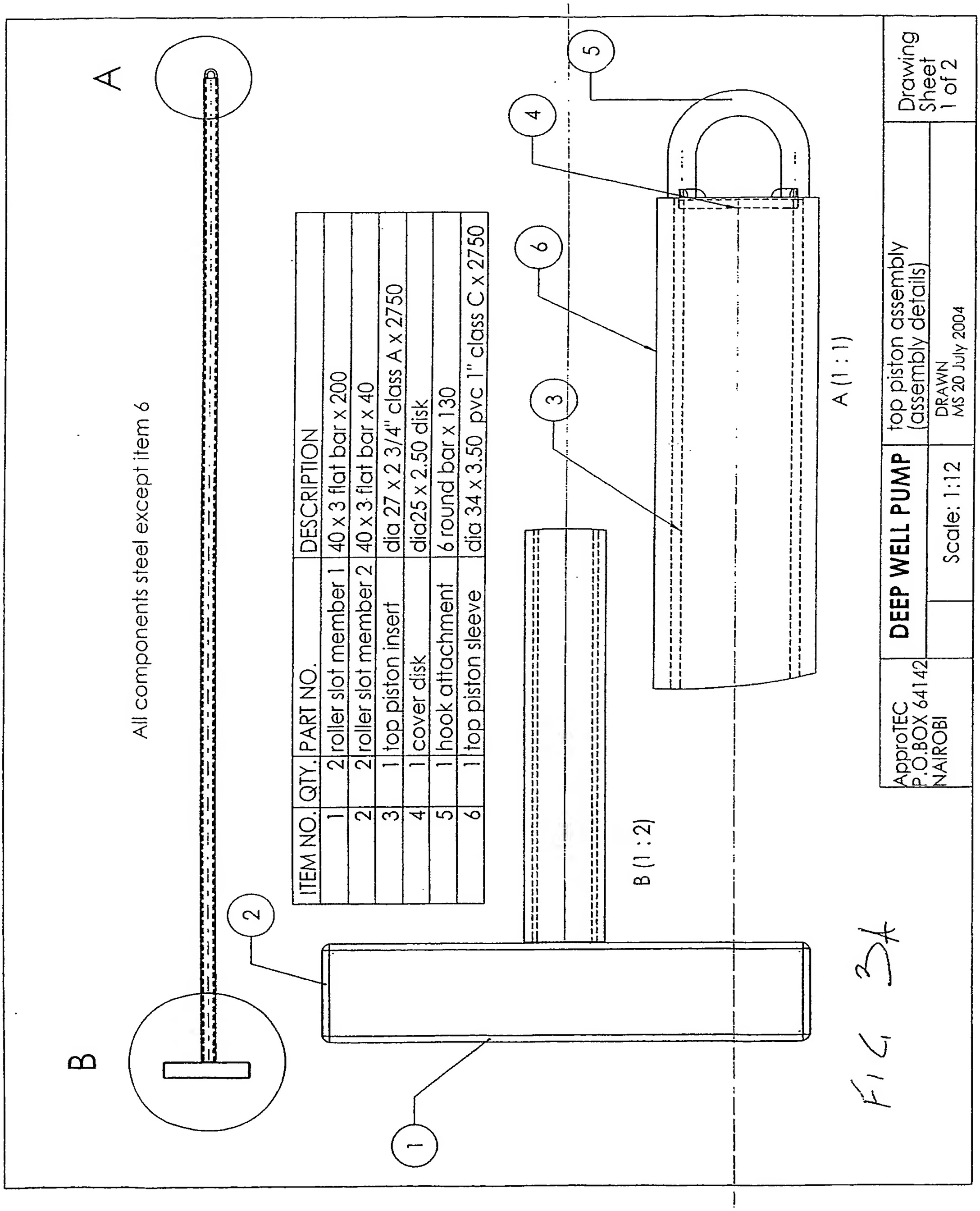

A
B
All components steel except item 6
ITEM NO. QTY. PART NO. DESCRIPTION
1 2 roller slot member 1 40 x 3 flat bar x 200
2 2 roller slot member 2 40 x 3 flat bar x 40
3 1 top piston insert dia 27 x 2 3/4" class A x 2750
4 1 cover disk dia25 x 2.50 disk
5 1 hook attachment 6 round bar x 130
6 1 top piston sleeve dia 34 x 3.50 pvc 1" class C x 2
A (1 : 1)
B (1 : 2)
Drawing Sheet 1 of 2
ApproTEC P.O.BOX 64142 NAIROBI
DEEP WELL PUMP
Scale: 1:12
top piston assembly (assembly details)
DRAWN MS 20 July 2004

FIG 3A

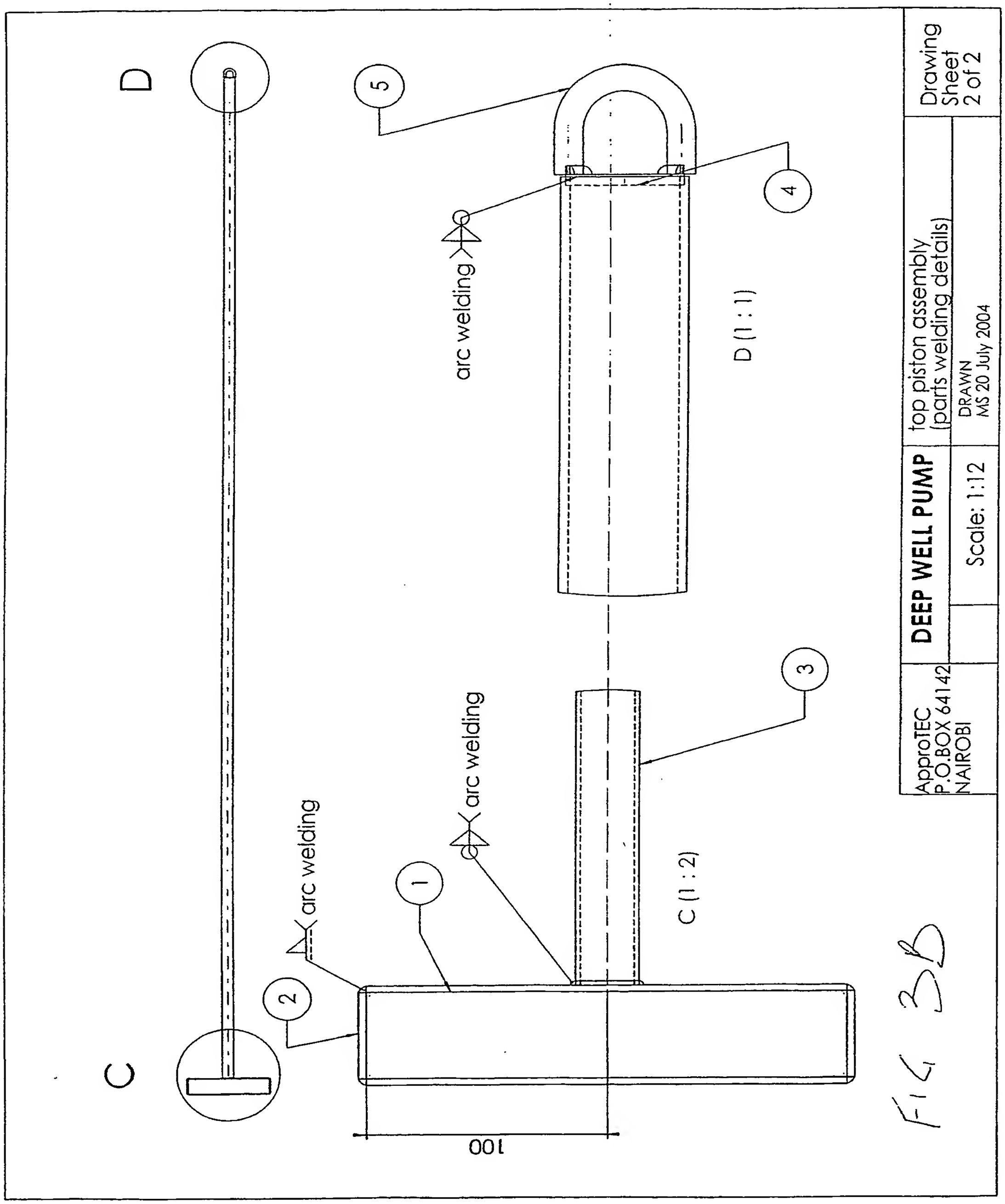
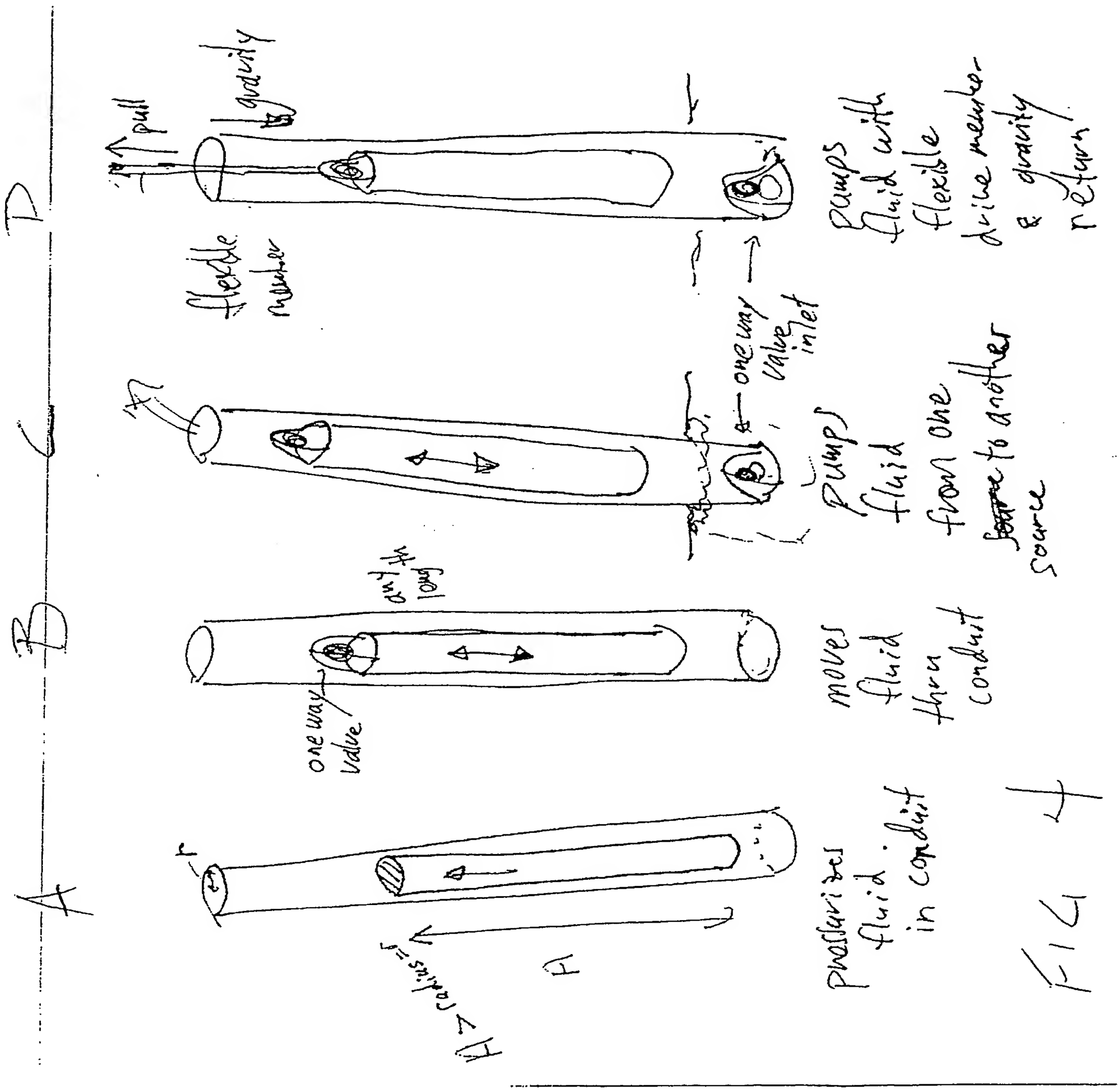
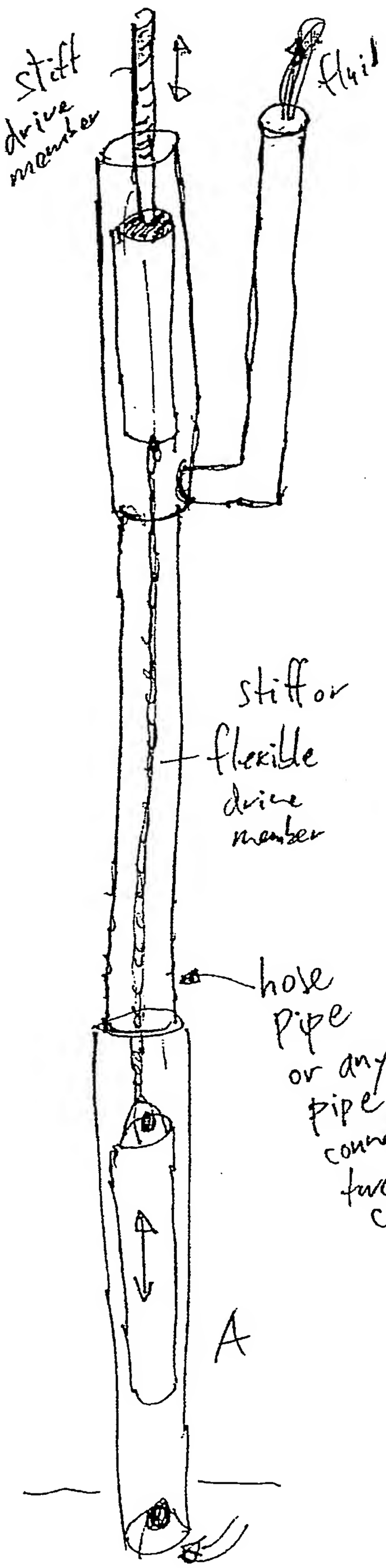
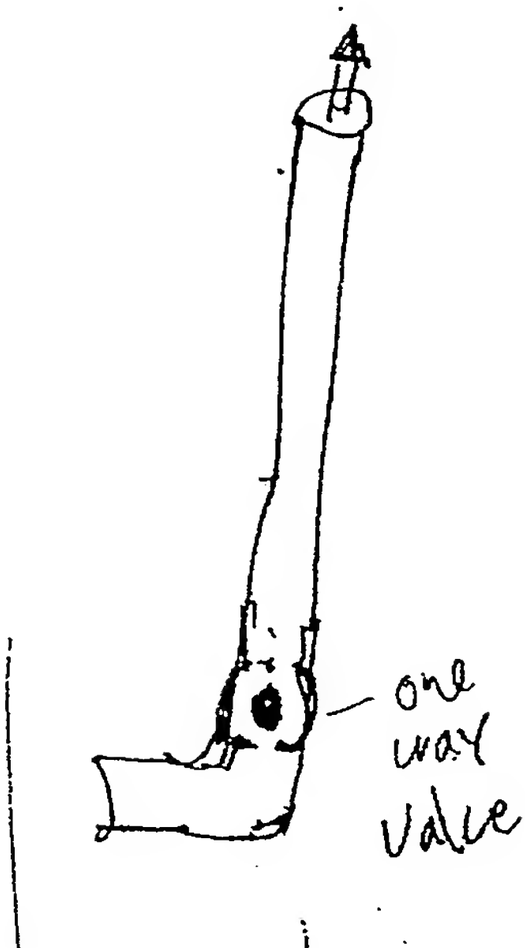

D
C
5
4
3
2
1
arc welding
arc welding
arc welding
arc welding
100
D (1 : 1)
C (1 : 2)
Drawing Sheet 2 of 2
top piston assembly (parts welding details)
DRAWN MS 20 July 2004
Scale: 1:12
DEEP WELL PUMP
ApproTEC P.O.BOX 64142 NAIROBI

FIG 3B


pull
gravity
flexible member
one way valve inlet
pumps fluid with flexible drive member & gravity return
one way valve
pump fluid
moves fluid thru conduit
pump fluid from one source to another
flexible member & gravity return fluid in conduit


stiff drive member
fluid
stiff or flexible drive member
hose pipe or any pipe connecting two cylinders.
A


one way valve
Same as A
B

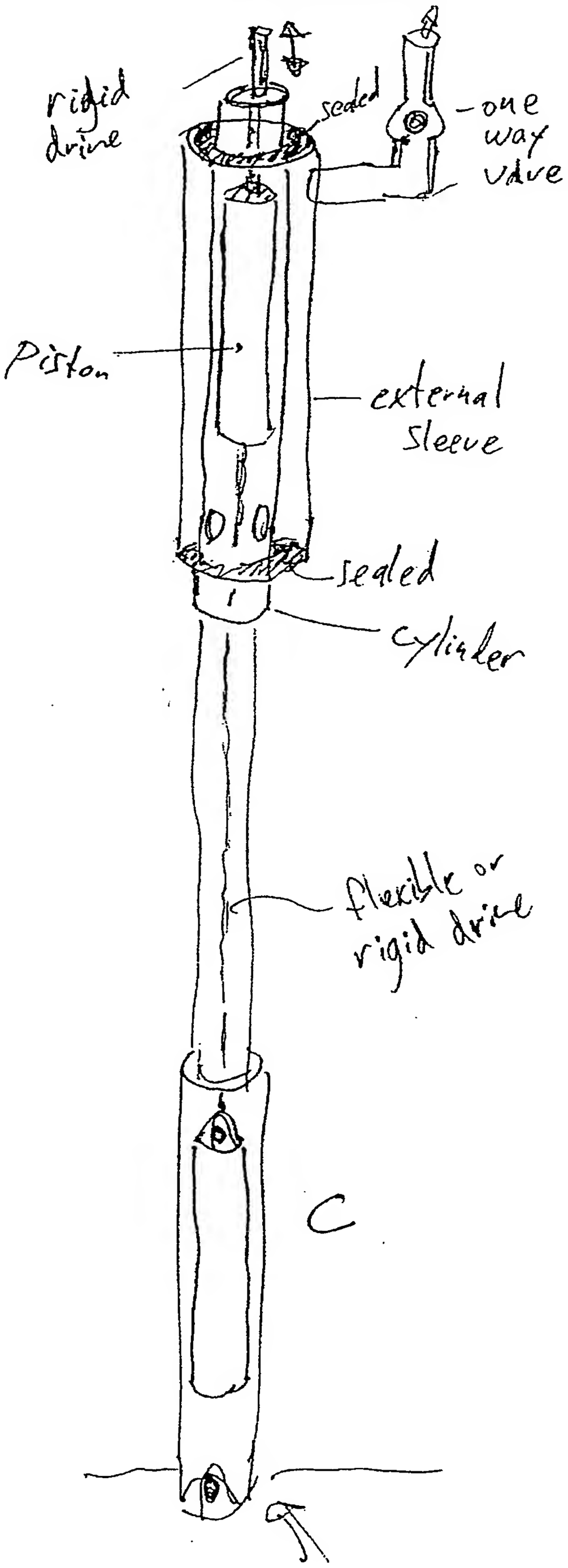

rigid drive
sealed
one way valve
Piston
external sleeve
sealed
cylinder
flexible or rigid drive
C

FIG 5

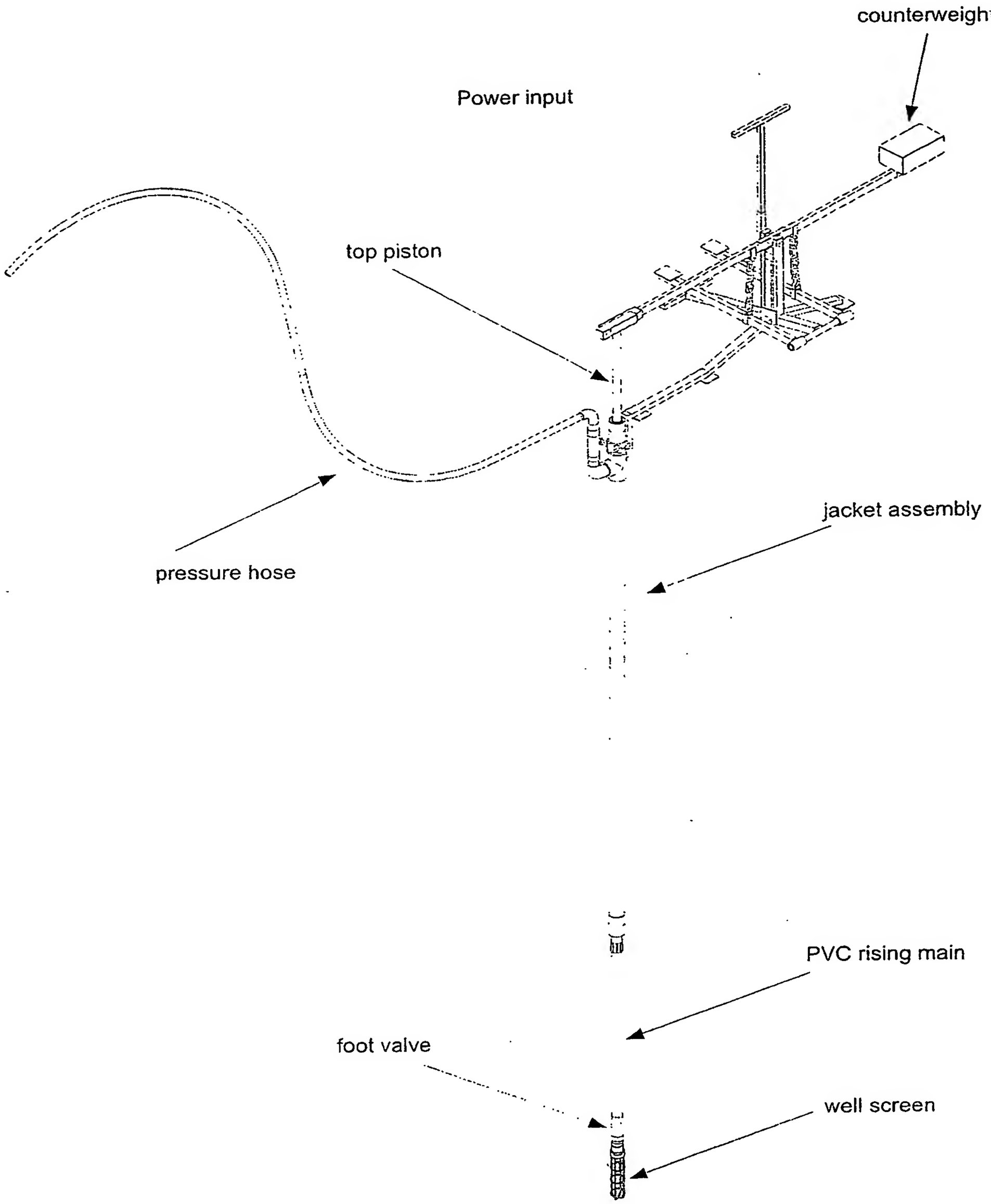

counterweight
Power input
top piston
pressure hose
jacket assembly
PVC rising main
foot valve
well screen

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/38130

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 372,888 A (BEAN) 08 November 1887 (08.11.1887), Figure 6.	--------- 1-9, 11, 12, 14-28, and 31
X --- Y	US 767,092 A (WALKER et aL.) 09 August 1904 (09.08.1904), Figure 1.	--------- 1-9, 11, 12, 14-28, and 31
X --- Y	US 205,699 A (SWAN) 02 July 1878 (02.07.1878), Figures 1 and 2.	--------- 1-9, 11, 12, 14-28, and 31
Y	US 6,622,612 B2 (NOTZON) 23 September 2003 (23.09.2003), Figure 1, column 2 lines 43-61.	1-31
Y	US 6,341,782 B1 (ETSION) 29 January 2002 (09.01.2002), Figure 1, 5, 6a, 6b, 7, column 6 lines 24-41.	1-31
A	US 2,633,808 A (WEBBER) 07 April 1953 (07.04.1953), Figures 1-3.	1-31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/38130

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : FO4B 53/12
US CL : 417/548
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 417/548,545,554,555.1,555.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 724,569 A (GRAGERT) 07 April 1903 (07.04.1903), Figure 1 and 2.	---------- 1-8, 11-13, 15-19, and 21-27
X --- Y	US 1,520,621 A (WATKINS) 29 May 1924 (29.05.1924), Figure 1.	---------- 1-5, 11, 12, 15-17, and 23-26
X --- Y	US 1,012,917 A (ROCKOLA) 26 December 1911 (26.12.1911), Figure 2.	---------- 1-31
X --- Y	US 909,676 A (ROCKOLA) 12 January 1909 (12.12.1909), Figure 2.	---------- 1-31

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 March 2005 (16.03.2005)	05 APR 2005
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703) 305-3230	Authorized officer Cheryl Tyler Shawn A. Greene for Telephone No. (571) 272 4832

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